Assignment 4

This study examines MRI data to understand how dementia alters brain volume over time and whether these changes vary between genders. Such insights are crucial for advancing dementia research and developing targeted interventions. The data derived from a longitudinal study allows us to explore these relationships in depth, forming the basis for our key research questions on the temporal impact of dementia and potential gender differences.

My Research Questions are:

1. How does dementia impact brain volume over time?
2. Are there gender differences in brain volume change associated with dementia?

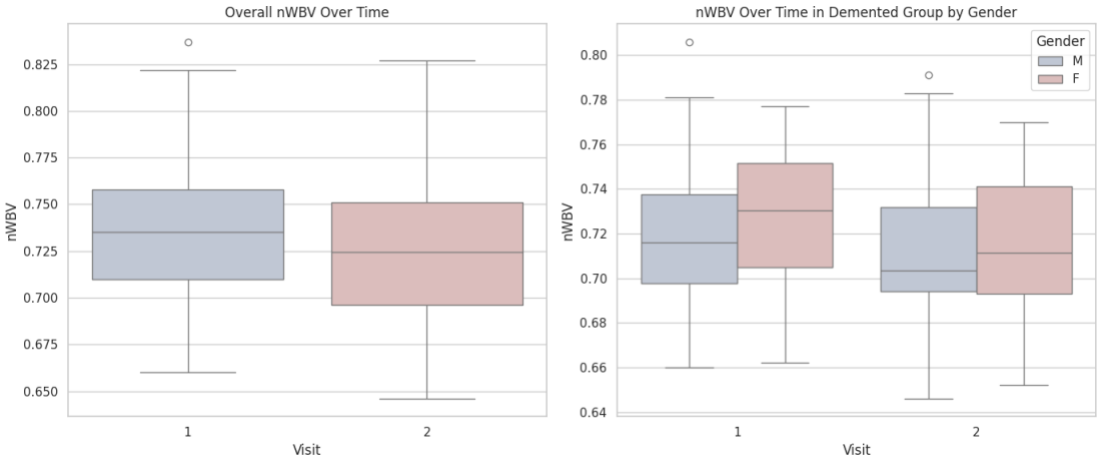
Dataset Overview

Significance of key variables:

- **Subject ID**: Identifier for subjects in the study.
- **MRI ID**: Unique ID for each MRI scan.
- **Group**: Classification of subjects as 'Demented' or 'Nondemented'.
- **Visit**: The number of visits each subject has made.
- **MR Delay**: Time interval between visits.
- **M/F**: Gender of the subjects.
- **Hand**: Dominant hand of the subjects.
- **Age**: Age of the subjects.
- **EDUC**: Years of education.
- **SES**: Socioeconomic status.
- **MMSE**: Mini-Mental State Examination score to assess cognitive status.
- **CDR**: Clinical Dementia Rating.
- **eTIV**: Estimated Total Intracranial Volume.
- **nWBV**: Normalized Whole Brain Volume.
- **ASF**: Atlas Scaling Factor (used to adjust volumes for head size).

Exploratory Data Analysis (EDA)

I generate two boxplots to analyze the normalized whole brain volume (nWBV) over time, for all subjects, and specifically within the Demented group by gender. Let's conduct an Exploratory Data Analysis (EDA) based on the visualizations generated.



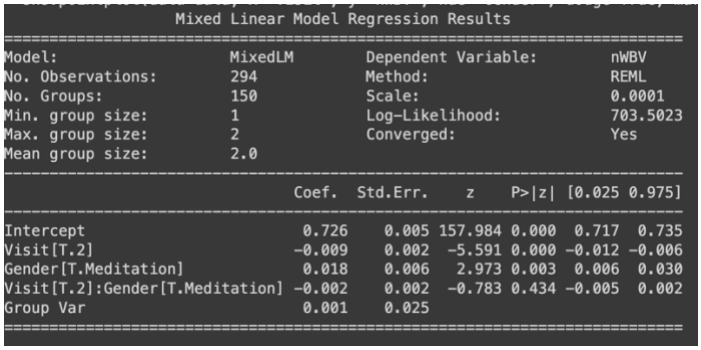
The first plot on the left titled 'Overall nWBV Over Time' shows the distribution of nWBV for all subjects across two visits. It uses a simple color palette, which helps to distinguish between the time. The median value appears to have decreased when time increased, which might suggest a decrease in brain volume over time for the population under study. The presence of outliers above the upper whisker in both visits indicates there are subjects with nWBV measurements significantly higher than the rest.

The second plot on the right titled 'nWBV Over Time in Demented Group by Gender' shows the distribution of nWBV specifically for the subset of subjects who are categorized as 'Demented', with the data separated by gender. This plot uses a color distinction to represent different genders: one color for males and another for females. It shows the median nWBV separately for each gender at two different visits. There seems to be a noticeable overlap in the IQR between males and females, but it is clear that the median nWBV for both genders decreases from the first to the second visit. This plot also contains outliers, suggesting individual variabilities within the genders.

In summary, The analysis shows that brain volume tends to decrease over time in patients with dementia. Both men and women show a drop in median brain volume across visits, with men exhibiting more variation. Further statistical testing could elucidate these trends and examine the impact of additional variables on nWBV changes.

mixed-effects model：

The mixed-effects model has been successfully fitted with the revised data and formula, and here are the updated results:



Mixed Linear Model Regression Results

Model:	MixedLM	Dependent Variable:	nWBV
No. Observations:	294	Method:	REML
No. Groups:	150	Scale:	0.0001
Min. group size:	1	Log-Likelihood:	703.5023
Max. group size:	2	Converged:	Yes
Mean group size:	2.0		

	Coef.	Std.Err.	z	P>|z|	[0.025	0.975]
Intercept	0.726	0.005	157.984	0.000	0.717	0.735
Visit[T.2]	−0.009	0.002	−5.591	0.000	−0.012	−0.006
Gender[T.Meditation]	0.018	0.006	2.973	0.003	0.006	0.030
Visit[T.2]:Gender[T.Meditation]	−0.002	0.002	−0.783	0.434	−0.005	0.002
Group Var	0.001	0.025				

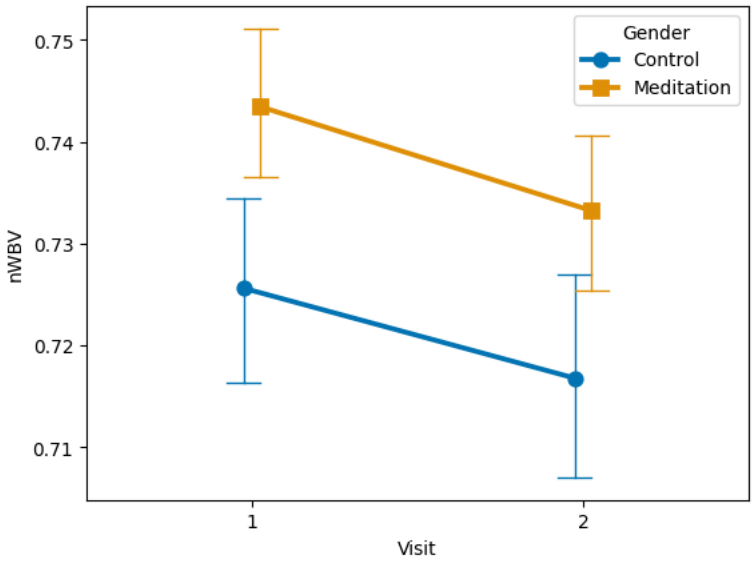
Mixed-Effects Model Results

- **Intercept (Baseline nWBV for Control Group at Visit 1)**: The estimated baseline nWBV is 0.726, which is substantially different from zero, indicating a significant average brain volume at the start of the study for the control group.
- **Visit Effect (Change from Visit 1 to Visit 2)**: The coefficient for Visit[T.2] is -0.009. This suggests that, on average, there is a small but significant decrease in nWBV across all participants from the first to the second visit ($p < 0.001$).
- **Gender Effect (Difference between Control and Meditation at Baseline)**: The coefficient for Gender[T.Meditation] is 0.018, indicating that the meditation group has a significantly higher average nWBV at the start of the

study compared to the control group (p = 0.003).

- **Interaction Effect (Difference in nWBV Change Over Time Between Genders)**: The interaction term Visit[T.2]:Gender[T.Meditation] is -0.002, which is not significant (p = 0.434). This implies that the rate of change in nWBV from Visit 1 to Visit 2 does not differ substantially between the control and meditation groups.

Boxplot



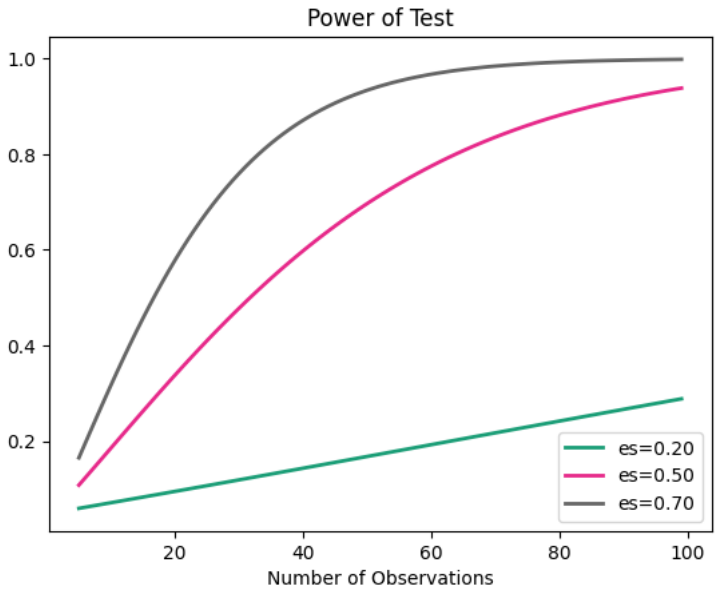
The point plot visualization shows the nWBV by visit and gender, reflecting the pattern detected in the statistical model. Both groups experience a decrease in nWBV by Visit 2, with the meditation group maintaining a slightly higher nWBV. The confidence intervals overlap significantly, especially at Visit 2, indicating no clear evidence of a difference in the rate of change between the two groups.

To be more specifically, The group summary statistics provide the mean and standard deviation of nWBV for each combination of Visit and Gender, rounded to two decimal places:

		mean	std
Visit	Gender		
1	Control	0.73	0.04
	Meditation	0.74	0.04
2	Control	0.72	0.04
	Meditation	0.73	0.04

Both groups show a decrease in mean nWBV from Visit 1 to Visit 2. The meditation group consistently shows a higher mean nWBV than the control group across both visits. The standard deviations are equal across groups and visits, suggesting similar variability within each group.

Box Plot for Power of T-test



The provided graph shows that the ability of a test to detect a true effect (power) increases with both the number of observations and the magnitude of the effect size. A larger effect size requires fewer observations to achieve high power. According to the calculation provided, for a large effect size of 0.7, about 46 participants are needed to have a 91% chance of detecting a true effect at a 5% significance level.

I also write a simulation for conducting a power analysis using a two-sample t-test, which is commonly used to determine if there are significant differences between two independent groups. The result of 0.9158 indicates that in approximately 91.58% of the simulation runs, the null hypothesis was rejected, meaning the test was able to detect the effect size of 0.7 with the given sample size. This estimated power is very close to the desired power level of 91% from the earlier power analysis. This high power level suggests that the sample size chosen is adequate for detecting a large effect size in most cases, ensuring the robustness and reliability of the experimental findings.

In summary, the data shows that brain size tends to get smaller over time in people with dementia, and this shrinkage happens for both men and women. Even though the group that practiced meditation started with a slightly larger brain size, as time went on, their brain size reduced at a similar rate to those who didn't meditate. The tests we did also show that the number of people we studied is enough to be confident in these results. Overall, the study gives us a clear picture of how brain size changes in dementia and that meditation doesn't seem to change this process.